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Sustainable reference methodology for energy end-use efficiency data in the EU

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Abstract

One of the most important goals of the European energy policy involves the implementation of energy-efficiency measures in large scale so as to promote sustainable development in the European Union (EU) level. The multidimensional character of energy end-use efficiency (EEE) necessitates the collection of a number of related data, apart from the performance and system parameters data, such as socio-economic (e.g., employment, turnover) and Research and Development (R&D) expenditures. Moreover, improved co-ordination of EEE programmes and policies of the community and the member states so as a unified acceptable system to be developed for the monitoring of the EEE data with respect to the existing targets is of significant importance. Even though data-gathering efforts have been implemented, a lot of fragmented data and deduced findings are currently available, which sometimes lack consistency and verification. In this context, the main aim of the paper is to present a sustainable reference methodology for validating EEE data in EU, through the review of existing approaches and methods, defining of most relevant inconsistencies and gaps and provision of recommendations for improvements in EEE data aggregation and statistical interpretation, taking into consideration the related analysis of statisticians, energy technology experts and energy socio-economists.

Keywords: Energy end-use efficiency data; EU; Sustainability; Validation

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Contents

1. Introduction

Based on the European Commission's (EC) Green paper, it is estimated that by 2030, on the basis of present trends, the EU will be 90% dependent on imports for its oil requirements and 80% dependent on gas. Total consumption is currently around 1.725 Mtoe. Estimations indicate that, if current trends continue, consumption will reach 1.900 Mtoe in 2020. Moreover, it is estimated that if no measures at all were taken, at this moment the EU-25 would be facing a primary energy demand of approximately 2.550 Mtoe [1]. It can be therefore highlighted the important results achieved till now in the energy consumption's reduction for the period after the first oil crisis through energy efficiency as well as the huge unexploited energy-efficiency potential. With today's most advanced technology, it is certainly possible to save around 20% of the energy consumption of the EU member states. Thus, one of the most important goals of the European energy policy involves the implementation of energy-efficiency measures in large scale so as to promote sustainable development in an EU level. This policy direction is shaped in order to encounter the challenges of the Kyoto Protocol's emission commitments, the security of energy supply and the increase of competitiveness [1,2].

Indeed, energy efficiency could contribute to the reduction of the current energy consumption by at least 20%, which is equivalent to the savings of 60 billion euros annually. Moreover, the same studies conclude that an average EU household could save between 200 and 1.000 euros per year in a cost effective manner, depending on its energy consumption [3–5]. On the other hand, the energy-efficiency industry's boom will result in the creation of high-quality working opportunities that directly or indirectly may even reach 1 million jobs [6]. It is indicatively mentioned that only in the United Kingdom,

where there is a wide range of energy-efficiency programmes and initiatives, the last decade more than approximately 55.000 new jobs have been created [7]. Moreover, the R&D budget dedicated by European Commission (EC) for energy-efficiency's promotion for the period 2007–2013 through the programme 'Intelligent Energy—Europe' reaches 780 million euros. The programme supports a broad range of promotional activities and address non-technological barriers (legal, financial, institutional, cultural, social) [1].

With respect to the above, currently often is the case where clearly defined criteria for correct data visualization and interpretation are missing. As a result, this gap leads in the creation of a nebulous picture on the existing energy end-use efficiency (EEE) data and in the insufficient contribution of all required parameters (social welfare, employment opportunities, environmental protection) in the decision making process. The multi-dimensional character of EEE necessitates the collection of a number of related data, apart from the performance and system parameters data, such as socioeconomic (e.g., employment, turnover) and R&D expenditures. In this context, policy-makers as well as individuals in the democratic society will be able to trigger specific answers to urgent questions, taking into consideration not only the economic feasibility of the examined options but their social and environmental acceptability as well.

In addition to this, the monitoring of the EEE data with respect to existing target setting is of significant importance. Significant data validation and data completion capacity is needed in the framework of the EU sustainability policy. Already in the Green Paper "Doing more with less" [1] the need for monitoring progress, timescale and costs of EU energy policy and measures is identified. Moreover, a number of EEE measure have been set, among which the ones of the directive on the energy performance of buildings (COM 2002/91/EC) [8], on combined heat and power generation (COM 2004/8/EC) [9], on the energy labelling of ovens (COM 2002/40/EC) [10] and air conditioners (COM 2002/31/EC) [11] in the residential sector, in the last Directive 2006/32/EC [12] on EEE in final consumption and energy services, and the Action Plan for Energy Efficiency, aiming at mobilizing the general public and policy-makers towards realization of EU's potential through a framework of policies and measures [13]. In all the abovementioned, the importance of improved co-ordination of programmes and policies of the community and the member states so as a unified acceptable system to be developed, was underlined.

Even though significant data gathering and monitoring efforts have been implemented, a lot of fragmented data and deduced findings are currently available, which lack consistency and verification. Often are even missing clearly defined criteria for correct data visualization and interpretation. In addition to this, data on Europe's EEE implementation are not yet sufficiently interpreted in its socio-economic context of human resources, policy measures efficiency, industrial stakeholders' and customers' choices, worldwide societal costs or environmental impact. Where this was already done in parts and with highly specific approaches, the results appear too often as dependent on non-typical input data. Also often the "consumers" of knowledge created this way are irritated by partially controversial results, e.g., from different modelling, and even different plain statistics. Another need is the lack of consistent historical data synopsis on all energy technology R&TD expenditure in the last decades (from the 1960s until today). This gap has caused a very nebulous picture about the efficiency of different EEE technology options, when looking at their derived societal or economic benefits (wealth production, job creation, environmental relief, impact for sustainable development, etc.).

With respect to the above, the main aim of the paper is to present a sustainable reference methodology for validating EEE data in the EU. The development of this methodology is mainly based on the review of existing methods and ends up with recommendations for improvements in EEE data aggregation and statistical interpretation, taking into consideration the related analysis of statisticians, energy technology experts and energy socio-economists.

The validated EEE data are important for a number of stakeholders, who cover all layers of involved actors, namely:

- *Data providers*: This category may constitute of private or public, regional, national or international contributing institutions. They may range from national ministries, industrial or trade organizations, NGOs to singular experts.
- *Decision-makers*: This category refers to persons that require harmonized data, that will support their decision making process. Therefore, this layer includes policy-makers at EU, national and also regional level, as well as policy proposing experts working in governmental bodies, agencies, European economic interest grouping (EEIGs), and in the "policy-near" scientific community. Also included are interested decision-makers in industry, trade and education.
- *Public*: This category comprises all interested citizens in new energy technologies, who want to be updated on the recent developments.

Apart from the introduction, the current paper is structured along seven (7) parts. In particular, Section 2 presents the approach adopted in the current study for validating the EEE data as well as the basic steps followed. Sections 3–7 are devoted to the presentation of the performance, potential, socio-economic, R&D expenditure and system parameters data, respectively. Finally, in Section 8, the most important conclusions drawn up from this paper are illustrated.

2. The approach

Indeed, one of the main priorities of the EC is the establishment of a regular data collection system in the member states. The EC has financed a number of surveys and specific data improvement actions towards this direction in the past years. In this context, the analysis that follows is largely based on the context of a project funded by the EC's FP6 programme that is being realized from the begging of 2005. Its basic goal is the enhancement of the timely availability, validation and traceable quality of data concerning renewable energy and energy end-use efficiency. The final aim is the establishment of a "one-stop-shop" for the EU (including accession member states) for policy and decision-makers, serving with unbiased and more complete and validated data on energy-efficient technologies. Most of the information and data presented in this section have been derived from the activities carried out within this project and the deliverables produced.

In particular, the approach is based on selected information and data by publications of international organisations, the kind contribution of experts, as well as the results of the implemented events, so as to incorporate the multidimensional character of EEE, as illustrated in Fig. 1.

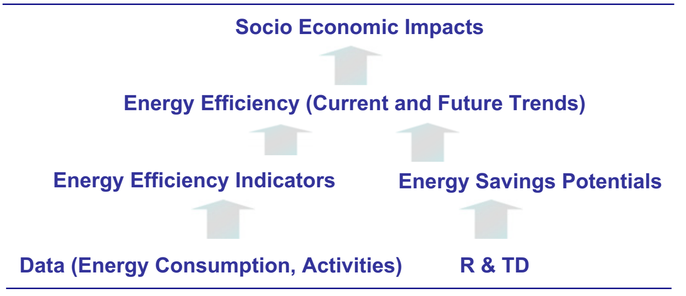

Fig. 1. The multidimensional character of EEE.

The proposed approach is structured along the following four steps, as described by Doukas et al. [14]:

Step I. *Formulation of the references' categories*: A brief categorization of required data towards the development of energy efficiency worldwide is analysed, based on international sources. More specifically, in the international literature exists a number of papers, regarding the existing energy-efficiency potential in a number of sectors, e.g., residential, industrial, etc., while this potential is being calculated by technology and by region, in order to identify the most promising energy-efficiency options [15,16]. Moreover, the wider socio-economic aspects of EEE and the way it is incorporated in the social agenda of sustainability are being thoroughly studied [17–19]. In the above framework, the impact of energy externalities and climate change on the performance and effectiveness of energy-efficiency measures is carefully reviewed and thoroughly examined [20–22]. Data regarding the effect of energy-efficiency technologies on several aspects of the society's development are also reviewed in extension [23,24]. In this context, the required EEE data to be investigated towards the development of energy efficiency worldwide were categorized to: (a) performance, (b) potential, (c) socio-economic, (d) R&D expenditures and (e) system parameters data.

Step II. *Review of methods*: An analytical review of existing methods for collecting EEE data, based on the experience from the common reporting rules from the international institutions, literature and from statistical databases (international, EU and national) was implemented. The literature review is based on the existing statistical offices, international and national energy agencies and also from the most competent research teams, who have a clear idea about EEE state of the art.

Step III. *Definitions and comparison*: This step played a significant role in the development of the current methodology. More analytically, an establishment of a common understanding between statisticians, energy technology experts and energy socio-economists for the most important parameters of the EEE data assumptions was implemented. As a result, the identification of data as well as structuring gaps (i.e., lacking data for certain regions, certain technologies, certain market segments or participants) was implemented by comparing the previously analysed methods.

Step IV. *Presentation and discussion of the results*: The last step included a final workshop (June 2006 in Paris—France), under the umbrella of IEA, where the specific references' categories as well as the definitions and categories and views of the related operators and stakeholders have been presented, discussed and finalized. During this

workshop, a distinguished audience constituted of managers of the above and other relevant organizations, participated and supported the fruitful dialogue regarding enhancing the reference methodology of EEE in the EU. As a result, a harmonized set of data-gathering categories, aggregation levels and best practice definitions was developed, in order to overcome inconsistencies taking into consideration the current status in the national, European as well as international level.

3. Performance data

3.1. Review of methods

The present data-gathering methods, existing assumptions and definitions for performance data approaches are briefly described in the following paragraphs:

- *IEA/Eurostat/OECD/UNECE/National statistics*: One of the most significant efforts for the promotion of energy efficiency at the European level was the ODYSSEE project [25]. The data in the ODYSSEE database come from both national and international sources, with a clear predominance of the national ones. Most of the data come from the usual national statistics (energy balances, national accounts, industrial and transport statistics) and semi-official national data sources. But in order to ensure a compatibility of the national data, harmonized definitions both for the energy and activity data were developed (orientated at international practice, mainly EUROSTAT and OECD/IEA), to which the national data have to be adapted, if necessary. The cooperating organizations exceeding the national level are Eurostat, UNECE/UNDP, OECD and IEA. In the course of this project, the data and indicators included in the MURE database, were further improved and new indicators were developed, which go beyond the traditional energy-efficiency indicators and aim at improving the interpretation of trends observed on the energy efficiency indicators.
- *IEA energy indicators*: The IEA energy indicator project has been carried out in collaboration with governments and research institutes in 11 IEA member countries [26]. The indicators analysed under the umbrella of the IEA Energy Indicator Project are ratios combining energy data with an activity or a productive output of a sector. Both types of ratios are called "energy intensities". The geographical scope of the IEA Energy Indicator Project only covers IEA countries where consistent, detailed, and long-term data time-series are available. This group is referred to as the IEA-11 and contains: Australia, Denmark, Finland, France, Germany, Italy, Japan, Norway, Sweden, the United Kingdom, and the United States.

3.2. Definitions and comparisons

The above-mentioned national and international organizations and agencies still use different definitions of EEE performance data. Different types of indicators are considered to describe and characterize energy use and energy efficiency. The definitions of these ratios are presented briefly below [27–29]:

- Ratios relating energy consumption to data that describe activities driving consumption in end-use sectors. These ratios are commonly called "energy intensities".

- Indicators which distinguish between main components affecting energy use or energy intensity. In this case, usually factor decomposition methods are used in order to separate different impacts, especially the impact of structural changes within the economy or within an end-use sector on energy intensity.
- Aggregate indicators that combine the results of all indicators of a sector in order to assess the overall energy efficiency of a sector or of the whole economy.
- For cross-country comparisons, often are being used ratios which are adjusted for structural differences between countries (different climate, different economic structure).

Apart from the general definition of energy-efficiency indicators, the following definitions of data categories have to be considered:

- *Geographical definition*: Regional level, national level, supranational level (e.g. EU, IEA).
- *Level of disaggregation*: Whole economy, sectors, sub-sectors.
- *Data collection period and time period*, for which energy-efficiency indicators are calculated.
- *Data sources*: National sources, international sources, mix of national and international sources.
- *Methodology*: Simple ratios or intensities (energy/activity), decomposition analysis, aggregate indicators, measurement of energy and activity (in physical or monetary/economic terms).

4. Potential

4.1. Review of methods

The extensive literature review has provided a detailed overview of the methods used by organizations for the potential's estimation. In this framework, the following are being presented:

- *IPCC*: The early IPCC work on potentials has gradually been formalized and used in several works which denominate the potential into the following categories: theoretical, technical, techno-economical and market [30]. IPCC has further developed this sort of typology and has also taken into account the "barriers" that prevent potentials from being realized and "actions" to overcome the barriers. IPCC is, however, not limited to energy efficiency but described "mitigation potentials" in a global context. This IPCC approach is valuable in bringing in barriers and actions but this has been at the price of stringency. More particularly, in the IPCC approach the physical limit has a strange remark that can shift over time, while the market potential is already achieved at the beginning of the period [31].
- *World Energy Assessment*: The World Energy Assessment has also used a typology for their work which denominates the potential as follows: theoretical, technical, welfare potential (societal potential), economic potential, market trend potential (or expected potential) [32]. This approach is more stringent in definitions than the one used by IPCC but still loses on the margins, e.g., the definition on technical potential which is

characterized as "commercial", while at the same time is described as "regardless of costs-considerations".

4.2. Definitions and comparisons

The EEE potential categories to be considered are mentioned below:

- *Price levels* for supply, primarily from the consumers' point of view, since considerations on markets' adaptation towards acceptance is a major issue.
- *Nature of market organization* (and barriers) and estimation of their quantitative impact for reasons as above.
- *Performance characteristics* for technologies used to satisfy customer needs in households, industry, transportation, etc. These characteristics are distributed over a range and the data may have to be presented in formats that simplify calculation e.g., average, BAT, BAT+, median, quartiles, etc.
- *Price distribution* for different classes of technology performance as above if there is such differences that can be associated with energy performance.
- *Estimates on "accumulated volume"* of the technology to be observed and the cost for its production (to estimate learning curves), if possible.
- *Market penetration* of a certain technology to estimate saturation and uptake speed on market.

There are several variations to these potential categories. The IEA is presently working on the issues and has used concepts as "market-economic-technical-scientific" [33]. ACEEE has used the expressions "achievable-economic-technical" [34].

5. Socio-economic data

5.1. Review of methods

The review of existing EEE methodological approaches for the sustainable socio-economic data gathering is presented in the following paragraphs:

- *Eurostat*: The approach used in the Eurostat working papers for the "environment industry" is expected to be useful in guiding the research that follows regarding socio-economic data. According to these studies, the main descriptive variables used for appraising the EEE industry are turnover, investments and employment by sex and educational qualifications. Working papers were conducted for identifying the relationship between the environment, industry and employment and therefore for measuring the environment-related employment in France, Portugal, Sweden and the Netherlands by sex and educational qualifications [35–38].
- *Save programme*: In the framework of the Save programme, a huge amount of studies has been supported by Intelligent Energy Europe. A selected number of them on employment are mentioned below. According to the outputs of the Save programme "National and Local Employment Impacts of Energy-Efficiency Investment Programmes", the provision of clear indications to the employment effects of energy efficiency to policy-makers (at local, national and EU levels) is of crucial importance.

There are three main components to the employment impact of energy-efficiency investment programmes, namely the direct employment, the counterbalancing negative effect on employment in the energy supply industries and the secondary employment generation or loss. The Save project's study investigated short- and long-term impacts, both on total numbers of employed persons and on the skills mix utilized in the economy.

- *ETUC job creation under Kyoto protocol*: In this working document, the European Trade Union Confederation (ETUC) expressed that the goal of reducing carbon dioxide emissions represents enormous employment creation potential, particularly in respect of energy-efficiency techniques. This consensus is supported by a number of studies from a range of national institutes analysing the impact of climate change policies on employment in this working document [39].
- *UK energy efficiency and jobs*: Seven energy-efficiency investment programmes were studied in the report to identify the jobs created, by calculating the direct and indirect employment. The core of the report was the discussion in the case studies, relating to how businesses and individuals responded to the new employment opportunities arising from energy-efficiency programmes. The case studies also made an assessment of the cost effectiveness of the programmes in terms of energy savings [7].
- *ICLEI job creation through energy efficiency*: In the context of the ICLEI, 89 case studies were implemented. These case studies use successful examples of local environmental and development management to present key concepts for implementing sustainable development at the local level. Examples are from all over the world. Especially "Case Study 72—Job Creation through energy efficiency" combined local employment efforts and climate protection measures [40].
- *InterSEE project*: It provides an in-depth socio-economic analysis of successful activities in the field of energy efficiency in small medium enterprises (SME). In this context, a number of qualitative and quantitative criteria for successful industrial energy-efficiency activities and related programmes were presented [41].
- *LBNL*: For a number of end-use energy-efficiency projects, targeted to the building and industrial sector, the socio-economic impacts were examined. More specifically, the distribution of project benefits and costs were evaluated. Especially as concerns the socio-economic impacts, the cultural properties, distribution of income and wealth, employment rights, gender equity, induced development and other socio-cultural aspects, long-term income opportunities for local populations plants (jobs), public participation and capacity building and quality of life (local and regional) were analysed [42].
- *OECD*: The report "Towards more Sustainable Household Consumption patterns, Indicators to measure progress" is focused on the demand side and on household consumption patterns. Particularly, indicators to enhance policy-makers understanding of key trends in consumption levels and patterns and to get a better understanding of significant changes and of the forces driving these changes were developed [43].
- *DEPA*: According to a relevant DEPA report, the most important parameters identified for the household energy-efficiency socio-economic data are the demographic determinants, technology and infrastructure, economic factors, household composition, occupier behaviour, habituation and other social factors. The report goes on to also address the underlying social and cultural influences [44].

5.2. Definitions and comparisons

The energy end-use sectors most commonly referred to and analysed, regarding their socio-economic data in Eurostat and IEA are the industrial, the residential and the commercial and public sectors. Based on the review analysis, the following remarks can be made:

- *Eurostat variables for appraising EEE industry*: The approach used by Eurostat is expected to be useful in guiding the research that follows regarding socio-economic data. According to these studies, the main descriptive variables used for appraising the EEE industry are turnover, investments and employment by sex and educational qualifications [45].
- *Save programme*: The provision of clear indications to policy-makers (at local, national and EU levels) is of crucial importance, because they are related to the employment effects of energy efficiency. There are three main components to the employment impact of energy-efficiency investment programmes that should be analysed as follows [46]. The first one is direct employment, resulting from the manufacture, installation and operation of energy-efficiency products and processes, and in management of programme to promote these investments. The second one is the counterbalancing negative effect on employment in the energy supply industries resulting from any reductions in energy demand. Finally, the third component is the secondary employment generation or loss, resulting from increases or decreases in spending in sectors with differing labour intensities.

6. R&D expenditures

6.1. Review of methods

A thorough literature review has been carried out in order to collect and review the existing EEE definitions, assumptions, as well as approaches for the sustainable public and private energy Research Technological Development (R&TD) expenditures data gathering. In the above framework, the acquired review of methods is presented below:

- *Eurostat*: The organization covers all areas of R&TD in its GBAORD and GERD statistics. More specifically, it collects budget data in its GBAORD statistics and expenditure data in GERD. Especially, as concerns the data of GERD, they are collected through the annual R&TD questionnaires by source of funds for European economic area (EEA) countries (until 2001) [47].
- *IEA*: The organization focuses on energy in its R&TD questionnaire. IEA statistics on energy R&TD use a scientific/technical nomenclature and are collected by governmental R&TD financiers. Member countries interpret the IEA questionnaire and the underlying concepts and definitions differently or simply deviate for practical reasons from IEA guidelines. The IEA does not collect data on private R&TD expenditures. No institutional nomenclature is used [48].
- *PSI*: This project provides a full review and comparison of energy R&TD strategies for all European member states. National and EU energy R&TD expenditures are divided into five categories, among which the energy conservation. These databases contain

data on government expenditures presented in 1999 prices and exchange rates. Particularly, as concerns the energy conservation database, it is sufficiently developed and within this category, most countries focus on energy conservation in buildings [49].

- *Battelle project*: A number of reports were developed regarding the energy R&TD of eight countries among which France, Germany, Italy, The Netherlands and the United Kingdom. These reports include relevant expenditures data divided into four broad categories, including both governmental and private funds. Moreover, reports covering the R&TD expenditures from EU's programs (e.g., framework programmes) are also available [50–53].
- *Frascati manual*: R&TD comprises creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society and the use of this stock of knowledge to devise new applications. The term R&TD covers three activities: basic research, applied research and experimental development [54].
- *IEA energy technology R&TD statistics service* is a joint service of the Energy Statistics Division and the Energy Technology Policy Division of the IEA. The IEA database incorporates recent data on budgets in national currencies (in nominal and real prices) and presents economic indicators used for deflating the R&TD budgets and calculating indicators. In particular, the governmental energy technology R&TD budgets are submitted on an annual questionnaire every year to the IEA secretariat by appropriate administrations in national currencies. In the above questionnaire, the main EEE R&TD categories are the following: industry, residential and commercial, transportation, others conservation (this sector includes R&TD information based on the waste heat utilization) [55].
- *Global climate change group* at the Pacific Northwest National Laboratory (PNNL) defines energy R&TD, as the linked process by which an energy supply, energy end use, or carbon management technology moves from its conception in theory to its feasibility testing and small scale deployment [50–53,56–57].
- *European commission*: Energy R&TD encompasses activities such as basic and applied research as well as technology development and demonstration in all aspects of resource extraction and production (e.g., mining, drilling, refining, exploration), power generation (e.g., nuclear fission and fusion, fossil and RES), transmission, distribution and energy storage, energy efficiency and carbon management technologies [58].

6.2. Definitions and comparisons

According to Dooley [59], the energy R&TD data sources are divided into public and private. As concerns the national public R&TD, there are two broad categories:

- *Data from international agencies*: Statistics that are collected and reported by international organizations such as the IEA, the Organization for Economic Cooperation and Development and the United Nations. Generally, they are readily available in large, cross-sectional and longitudinal data sets.
- *Data from country-specific sources*: Statistics that are collected and reported by energy R&TD data sets that are built up through the collection and translation of country-specific data sources (e.g., budget documents, program plans).

Regarding the private energy R&TD data sources, they can be obtained from two broad classes of data sources:

- *Data from government ministries*: Census/data collection mandate that extends to energy industries. However, a small number of the advanced industrialized nations known to support energy R&TD have government ministries that periodically survey private sector firms within their borders asking about Energy R&TD investment levels.
- *Data from individual firms or collaborative R&TD enterprises*: Data collection from the firms themselves or from interfirm collaborative enterprises.

7. System parameters data

7.1. Review of methods

A number of interesting studies can be identified based on the analysis of methodological approaches for EEE technology data collection. The main characteristics of these studies are briefly presented as follows:

- *EC*: The surveys of energy consumption in households and the tertiary sector provided a statistically and scientifically valuable database for both sectors, which can be used for quantitative analyses of the energy consumption and its structural and socio demographical determinants [60].
- *IEA*: An extensive IEA study has been implemented for energy-efficient homes, where the energy-efficient end-use technologies of the residential sector were analysed [61]. Moreover, several other related IEA studies exist, such as the one on energy-efficient lighting [62].
- *LBNL*: LBNL has many reports for end-use energy-efficiency technologies, for approximately 90% of the primary energy consumed in the tertiary sector. The building and equipment data have been summarized in seven LBNL reports that characterize the use of the efficiency technologies in commercial buildings. However, the reports of LBNL described above are from 1994 and 1995, i.e., 10 years old, and do not cover the changes occurred from that time onwards [63–65].
- *ADL*: A study from Roth et al. [66] developed an updated energy consumption estimate for office equipment in commercial buildings. Furthermore, a recent study from Roth and Mc Kenney [67] provided a detailed energy consumption estimate for consumer electronics in residences.
- *EIA*: Most of the information available from EIA about the commercial buildings population and its energy use comes from the commercial buildings energy consumption survey (CBECS). The CBECS was first conducted in 1979; the eighth, and most recent survey, was conducted in 2003. The CBECS is a national sample survey that collects energy-related building characteristics data and energy consumption and expenditures data for commercial buildings in the United States [61,68].
- *WEC*: The study "energy end-use technologies for the 21st century" of WEC is divided into four parts covering technologies in the industry, buildings and transportation sectors. Each end-use technology area is discussed in terms of the system concept, the technology description and status, the R&TD goals and challenges and the commercialization and deployment [69].

- *FTA*: The FTAs studies and publication include a detailed technical description of many energy-efficiency end-use appliances for technologies for all end-use energy-efficiency sectors. There is no integrated report comprising technical data for a number of technologies in a sector but individual papers assessing specific appliances and technologies. These studies contain up-to-date information on the emerging technologies, their applications, as well as list of key parameters and information sources pertaining to the technologies [70].
- *CRES*: The study of CRES during the period 1995–1996 in Greece provides useful technological data for end-use appliances in the industrial sector, from an audit in the Greek energy sector. The categories in which technological data were collected are boilers and ovens, lighting, HVAC systems and industrial refrigeration [71].
- *Federal Ministry of Germany*: The surveys of energy consumption in households and the tertiary sector provided a statistically and scientifically valuable database for both sectors, which can be used for quantitative analyses of the energy consumption and its structural and socio-demographical determinants [72].

7.2. Definitions and comparisons

Based on the review analysis, the following remarks can be made:

- The available EEE system parameters data are mostly sporadic, as an integrated study on this data category does not exist. Moreover, the majority of national and international organizations and agencies still place emphasis in particular sectors, contributing in this way in the existence and continuation of non-harmonized data collection.
- The main final consumption sectors that are related to the energy end-use system parameters data in the "Eurostat energy balances" are industry and transport. The "ODYSSEE's energy-efficiency indicator project" provides indicators for energy-efficiency evaluation of a variety of technologies at the industrial, transportation, services and households sectorial level. The energy end-use sectors most commonly referred to and analysed in IEA are the industrial, transportation, residential, commercial, and electric power. The World Energy Council (WEC) study for the energy end-use technologies of the 21st century categorizes the technologies into industrial processes, buildings, transportation and cross-cutting technologies.
- In general, the ODYSSEE project can be considered as a very good basis on which a harmonized database on EEE system parameters data could be developed.

8. Conclusions

Energy end-use efficiency (EEE) is a continuously growing trend in the European energy policy, as a key means of achieving energy independence and increasing the citizens' living standards, by achieving same quality levels with less environmental pollution. The European Union, having realized the inevitability towards which the world is led to through the use of fossil fuels, has seized a number of opportunities to promote EEE among its member states, through financing a number of projects, under the framework of related programmes.

In this context, one of the main priorities of the European Commission (EC) is the establishment of a regular data collection system in the member states, so as to enhance the timely availability, validation and traceable quality of data concerning energy efficiency. This is indeed true, taking into consideration:

- The multidimensional character of EEE and consequently the collection of a number of related data, apart from the performance and system parameters ones, such as socio-economic and R&D expenditures.
- The monitoring of the EEE data in existing targets is of significant importance.
- The credibility of the available EEE data, since a lot of fragmented data and deduced findings currently exist, which lack consistency and verification.

Based on the above needs, a number of data providers exist:

- International data providers, such as the European Commission (notably DG RTD, DG TREN, DG JRC, EUROSTAT), the International Energy Agency (IEA) and the United Nations Economic Commission for Europe (UNECE);
- A number of projects, such as the ODYSSEE and the IEA energy indicator project.

Taking into consideration the results from the extensive review and comparisons implemented by the authors team in the context of the SRS NET & EEE project towards a sustainable reference system, the following observations can be made for each one of the previously mentioned EEE data categories:

- *Performance data*: Towards the direction of making the picture on the current energy situation a little less nebulous, there have been a number of initiatives and studies implemented till now. However, it seems that there are some difficulties in achieving this goal. Currently, the statistical data situation on energy consumption in households and especially the tertiary sector is considerably worse than in industry. Indeed, detailed tertiary sector surveys on energy performance data are more expensive because of the heterogeneous structure of the sector.
- *Potential*: From a comparative view of the existing approaches it can be considered that currently there is not a completely satisfactory approach for the description of the potential categories, contributing in this way in the vagueness of EEE potential's definitions. In this framework, when potential data is being collected, the following parameters have to be consistent: price levels, nature of market organization, performance characteristics, price distribution, estimates on "accumulated volume", market penetration.
- *Socio-economic data*: The empirical findings of a number of studies emphasize that the realization of an energy-efficiency's measure cannot be seen as a single and purely market-driven economic decision act, but requires the initiation and management of an energy related social process in the firm, involving various internal and external actors. Currently, a large number of socio-economic data is available for the majority of sectors, mainly on the direct employment and economic data. Difficulties still exist in collecting data on secondary employment, especially in the framework of the market conditions shaped under the deregulation trend.
- *R&D expenditures*: The existing R&D expenditures data cannot easily be compared across countries owing to differences in how R&TD activities and categories are defined

and in how the data are collected, since coordination among data providers within and among countries is quite restricted. Special attention should be paid to the fact that one of the most common problems in the existing R&D expenditures is the double counting in public and private time-series. This problem should be dealt with mainly in the national level, in order the aggregation of numbers to be possible to provide a clear and consistent picture at the EU level.

- *System parameters data*: As it is clearly illustrated in the previous sections, there is no integrated database for all energy end-use technology data, although significant efforts for collecting such data regarding the residential and commercial sector have been implemented. The IEA database could constitute the foundation of the SRS data collection, concerning the commercial and residential sector. Of course, it should be checked with regard to the crucial comments from the relevant studies of WEC and LBNL.

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